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Association between Noise levels and CO_2 Concentrations in Classrooms

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INTRODUCTION

The unfortunate but prevalent combination of high pupil density and insufficient ventilation in elementary schools often results in poor classroom air quality (e.g. Shendell et al., 2004; Dijken et al., 2005). For example, in more than half of the 700+ classrooms studied by Menå & Larsen (2010) in Danish schools, elevated CO_2 concentrations above 1000 ppm were observed during the school day. Also in classrooms, a too high noise level may obstruct pupils' recognition of the teacher's speech. In noisy classrooms, the extra effort required to identify and remember the words may result in fewer resources available for understanding and thus a reduced learning outcome (Kjellberg et al., 2008). It is likely that poor air quality may reduce pupil attention and stimulate noisy and non-concentrated behaviour. This study aimed at analyzing associations between concurrently measured classroom CO_2 concentrations and noise levels.

METHODOLOGIES

The measurements were carried out as part of a larger research project investigating the effect on teacher and pupil well-being and pupil learning of improving classroom acoustic conditions. CO_2 concentrations and the A-weighted sound pressure levels (L_Aeq) were measured during three one-week periods in six classrooms on each of two schools. The measurement periods represented the conditions before, after a sham renovation of one school and full renovation of the other, and after completed acoustic renovation of all classrooms. The renovation involved exchanging the existing ceiling with an acoustic ceiling of wood wool with cement admixture and addition of two acoustic pin boards on the side and back walls of the classrooms at a height of 1m above the floor. The dimension of the pin boards was 4 m x 1.2 m. Both schools were naturally ventilated by manual opening of windows and they were located in quiet suburban neighbourhoods.

During the measurement periods, each classroom was equipped with two noise dosimeters that logged sound pressure levels every second and a measurement station consisting of a datalogger with temperature, humidity and CO_2 transmitters. The noise dosimeters were hanging 1 m below the ceiling approximately in the center of the room and 2 m apart. The measurement station was located around 1 m beneath the ceiling either on a rafter or on a rear wall at a position where good mixing of the classroom air was expected and with little or no risk of exposure to direct sunlight. Temperature, humidity, and the CO2 concentration were logged in 5-min intervals. For each lesson during the schoolday when a classroom was occupied, the mean sound pressure level and the mean CO_2 concentration were determined and used in the analyses.

In an analysis of variance L_Aeq was used as the outcome variable and the factorized CO_2 concentration (<1000 ppm, 1000 – 1500 ppm, 1500 – 2000 ppm, 2000 – 2500 ppm, 2500 – 3000 ppm, >3000 ppm), renovation status, grade, classroom nested within school, school, and time of day (before or after the lunch break) were used as input variables. Residuals clearly followed a normal distribution as indicated graphically and tested with the Shapiro-Wilk Normality Test. Mixed effect modeling with an equivalent model, but using the non-factorized CO_2 concentration and classroom and school as random factors confirmed the results of the ANOVA.

RESULTS AND DISCUSSION

Distributed on lesson (1 = earliest and 6 = latest), Figure 1 shows boxplots of mean CO_2 concentrations (left) and mean sound pressure levels (right). Both parameters increased with the time of day. The CO_2 concentration was building up from the first lesson in the morning and decreased only slightly after the lunch break (between lessons 4 and 5). During the lunch break, the classrooms most likely were unoccupied or partly unoccupied and/or windows were opened. The sound pressure level also increased during the day and in particular before lunch.

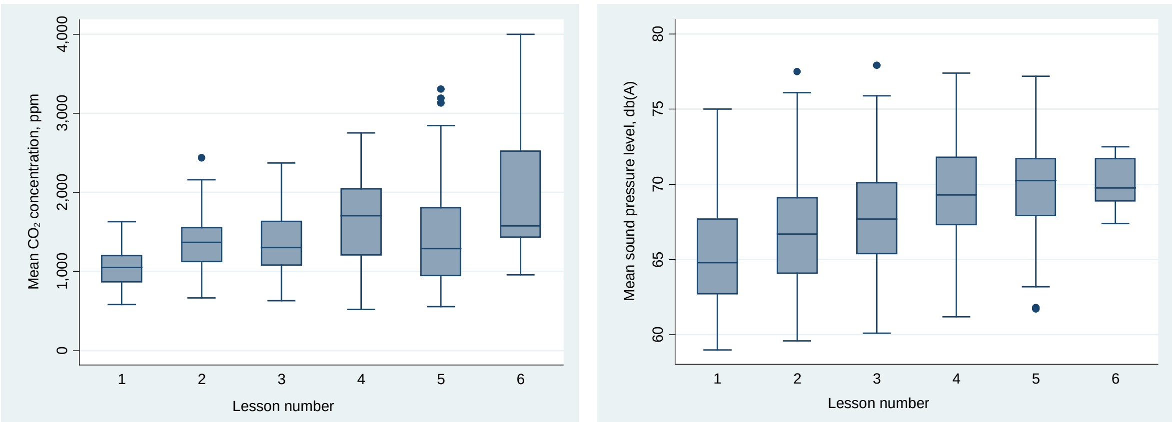

Figure 1. Mean of the CO_2 concentration (left) and of the sound pressure level (right) calculated for each lesson during the day when the classrooms were occupied.

It can be expected that pupils will be increasingly tired and therefore noisier as the school day progresses. Thus, some degree of co-linearity will exist between tiredness (confounded with time of day) and L_Aeq, and between tiredness and the CO_2 concentration. This complicated the statistical modeling and in attempt to adjust for this effect, a lump-factor was introduced that indicated if measurements were made before (lessons 1-4) or after lunch (lessons 5-6).

The analysis showed that L_Aeq increased significantly with increasing factorized CO_2 ($p < 0.001$). L_Aeq also varied with the time of day ($p < 0.001$), classroom ($p = 0.014$), and renovation status ($p < 0.001$). L_Aeq did not depend on the grade or the school.

The analysis indicated that pupils who have to spend the school day in classrooms with elevated CO_2 concentrations may be noisier than those who experience a better classroom air quality. In addition to the negative effect of poor air quality on pupil performance (Wargocki & Wyon, 2007; Bakó-Biró et al., 2012), insufficient ventilation may also distract pupils and cause a noisier classroom environment, which will affect negatively the learning outcome (National Committee Green Schools, 2006). Wargocki & Wyon (2007) made spot measurements of classroom noise, but the measured values indicate that measurements were made in empty classrooms. Bakó-Biró et al. (2012) did not report on noise measurements.

The schools included in this study had rather similar means of venting the classrooms, and the variation in the CO_2 concentration between classrooms probably mostly can be ascribed behavioural differences. We do not have data on the number of pupils that were present in the classrooms during the measurements. Different occupant density will affect both the CO_2 emission and the noise level in a classroom. At both schools the classes included in the study comprised around 22 - 23 pupils and only an insignificant effect on $L_A$eq of a different number of pupils present was expected. The classroom volume was larger on one school than on the other, which affected the build-up rate of the CO_2 concentration. However, the measured mean CO_2 concentrations were slightly higher at the school with the larger classrooms, but this did not cause the noise level to generally differ between schools.

The analysis described in this paper indicated an association between the CO_2 concentration and noise, but additional analyses are needed to confirm the findings. These analyses are ongoing and will be reported at a later stage.

CONCLUSIONS

This analysis indicated that elevated CO_2 concentrations in the classroom may be associated with elevated noise levels. Thus, insufficient ventilation and poor air quality seem to stimulate a noisier behavior among the pupils. However, the findings still need verification.

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REFERENCES

Bakó-Biró, Z., Clements-Croome, D. J., Kochhar, N., Awbi, H. B., & Williams, M. J. (2012). Ventilation rates in schools and pupils' performance. *Building and Environment*, *48*, 215–223. doi:10.1016/j.buildenv.2011.08.018

Dijken, F., Bronswijk, F., & Sundell, J. (2005). environment in Dutch primary schools and health of the pupils. In *Proceedings of Indoor Air 2005* (p. I(1): 623e7).

Kjellberg, A., Ljung, R., & Hallman, D. (2008). Recall of Words Heard in Noise, *1098*(November 2007), 1088–1098. doi:10.1002/acp

Menå, H., & Larsen, E. (2010). *Indoor environment in schools* (69 pages). International Centre for Indoor Environment and Energy, Technical University of Denmark. Lyngby.

National Committee to Review and Assess the Health Productivity Benefits of Green Schools, N. R. C. (2006). *Green Schools: Attributes for Health and Learning* (p. 192).

Shendell, D. G., Prill, R., Fisk, W. J., Apte, M. G., Blake, D., & Faulkner, D. (2004). Associations between classroom CO2 concentrations and student attendance in Washington and Idaho. *Indoor air*, *14*(5), 333–41. doi:10.1111/j.1600-0668.2004.00251.x

Wargocki, P., & Wyon, D. P. (2007). The Effects of Outdoor Air Supply Rate and Supply Air Filter Condition in Classrooms on the Performance of Schoolwork by Children (RP-1257). *HVAC&R Research*, *13*(2), 165–191.